JATROPHA HANDBOOK

2D EDITION

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CHAPTER 4 (OF 6)

Oil pressing and purification

ABBREVIATIONS

Oil recovery rate: the percentage of the present that is removed. A recovery rate of 100% means all the oil is removed from the seed. For jatropha this would be 0,41 liter per kg seed.
SVO (Straight Vegetable Oil): this is oil after pressing and cleaning that is ready to be used various purposes. Also referred to as PPO (pure plant oil).
Crude oil: Jatropha oil directly after pressing
Bleaching: an adsorptive process that removes all gross impurities such as meals, metal components, peroxides, products of oxidation, soap residue from alkali refining. Hydratable gums can also be removed in this step if the level is below 55 ppm [9].
Deodorizing: the only good way to remove Sulphur. In addition it removes some fatty acids [9].
Free fatty acids (FFA): exist in crude plant oils as a deterioration by-product of hydrolysis. In their free form, they are soluble in oil and insoluble in water and can therefore not easily be separated from the oil [9].
Hydrolysis: the conversion of glycerides into fatty acids and glycerol.

4 Oil pressing and purification

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4.1 Introduction

Basically, the process of gaining oil from oilseeds is as old as mankind. Although the means that are used for this purpose have evolved, it still entails the crushing of the seeds to extract the oil. There is not much practical experience with pressing of jatropha seeds to draw upon. GTZ (German Agency for Technological Co-operation) was one of the first organisations to be involved in jatropha pressing in the late 80s and early 90s. New studies on expelling and cleaning of jatropha started at other institutions, including the WUR (Wageningen University and Research Centre) and RUG (University Groningen) in the Netherlands. In addition to these big research institutes, smaller, practically oriented initiatives by jatropha enthusiasts have yielded interesting results.

The total production process from jatropha seeds to oil is displayed below. For each process step the paragraph that treats this specific topic is indicated.

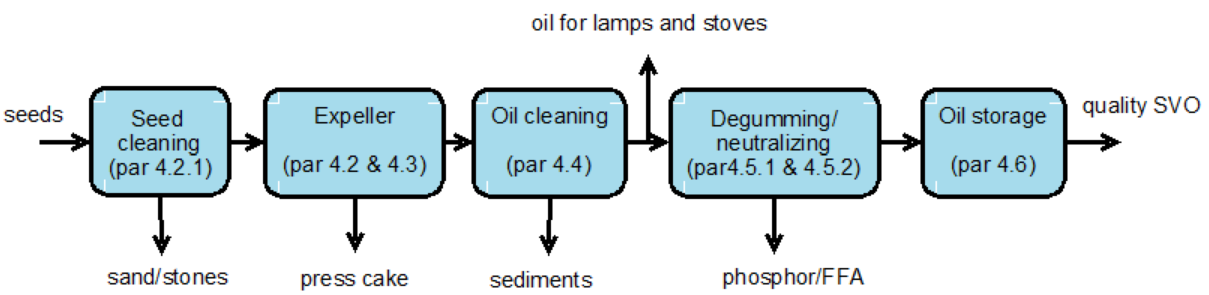

Figure 8 - Production steps for jatropha SVO production. Degumming and neutralization are only required if high amounts of FFA (free fatty acids) and phosphor are present. The values in the DIN V 51605 standards, as shown in figure 23, are a good reference.

This chapter discusses mechanical oil extraction methods and oil quality aspects for jatropha oil production. Mechanical oil extraction means using some sort of pressing machine to force oil out of the oil seeds. Multiple technologies are available for oil extraction. The selection is mainly a trade-off between the acceptable complexity, costs of technology and the required oil quality. Production scale is an important limiting factor in the choice of technology. Oil extraction is one aspect of oil production. After pressing, the jatropha oil needs further purification before it can be used. Different ways of solid-liquid separation are therefore discussed. Section 4.2 treats the subject of mechanical oil extraction. Press technologies are discussed and suggestions for jatropha are made in section 4.3. Section 4.4 elaborates on oil cleaning methods. General quality aspects for vegetable oil to be used as fuel are discussed in section 4.5. Section 4.6 treats quality related storage issues.

4.2 Mechanical oil extraction

There are different ways to extract oil from oilseeds. One way is mechanical expression using a machine to exert pressure on the oilseeds in order to remove the oil. A second method for oil removal is solvent extraction, where a solvent is added to pre-crushed seeds in which the oil dissolves. The oil can later be recovered from the solvent. In industrial oil mills, theses two processes -- mechanical expression and solvent extraction -- are often combined to obtain the highest yields. The oil recovery from mechanical extraction is limited to 90-95% of the oil present in the seeds, whereas solvent extraction can yield up to 99%. Solvent extraction is a complex, large-scale solution involving dangerous chemicals.

Since this handbook focuses on small-scale applications, solvent extraction should not be considered a possibility. Mechanical extraction using an expeller is the most popular oil extraction method for consumable oils as it is simple, continuous, flexible and safe.

4.2.1 Cleaning and checking the seeds

Cleaning and checking the seeds can reduce machine wear. Most contamination consists of sand, woody material and stones, the last of which are most destructive to the expeller. The most common way to remove stones and sand is by thresher or a (vibrating) sieve. The choice between manual and mechanized sieving depends on production capacity.

4.2.2 The pressing process

During the pressing process the seeds are fed into the seed hopper and then simultaneously crushed and transported in the direction of a restriction (also referred to as 'die' or 'nozzle') by a rotating screw (often called 'worm'). As the feeding section of the expeller is loosely filled with seed material, the first step of the process consists of rolling, breaking, displacement and the removal of air from inter-material voids. As soon as the voids diminish the seeds start to resist the applied force through mutual contact and deformation. The continuous transport of new material from the hopper causes pressure to increase to a level needed to overcome the nozzle. At this point the press is 'in operation'. The built-up pressure causes the oil to be removed from the solid material inside the expeller. For more detail see [2].

4.2.3 Important parameters when pressing

When designing or installing a facility to press jatropha seeds it is useful to know the main variables affecting the oil recovery and oil quality. The information given below applies to the expelling process in general and might not apply to specific cases [2]. Figure 1 subsequently summarizes the influence and impact of the variables.

Press parameters		Oil recovery	Pressure	Temperature	Throughput	Energy/liter
RPM	↓	↑	↑	-	↓	↑
restriction size	↓	↑	↑	↑	-	↑
Seed treatments						
heating	↑	-	↓	↑	-	↓
flaking		↓	-	↓	-	↓
moisture content	↓	↑	↑	↑	↓	↑
hull fraction	↓	↓	↓	↓	↓	↓
boiling		↑	↑	↑	-	↑

Figure 1 - The effect of press parameters on output and process parameters. The upward arrows indicate an increase of a variable and a downward arrows a decrease [2]. RPM indicates the rotational speed of the screw in rounds per minute, restriction size is the opening where presscake leaves the expeller, and flaking is grinding into small peaces.

4.2.3.1 Oil recovery

The amount of oil that can be recovered from the seeds is affected by:

- **Throughput:** the amount of material that is processed per unit of time (kg/hr). Higher throughput gives lower oil recovery per kg of seeds, due to shorter residence time in the press. Throughput can be affected by changing the rotational speed of the screw.
- **Oil point pressure**: the pressure at which the oil starts to flow from the seeds. If seeds can, for example, be manipulated so that the oil point pressure is reduced, it becomes easier to extract the oil.
- **Pressure**: at higher pressure more oil is recovered from the seeds. However, the higher pressure forces more solid particles through the oil outlet of the press. This makes cleaning more difficult. Typical operating pressures for engine-driven presses are in a range of 50-150 bar.
- **Nozzle size**: smaller nozzle size leads to higher pressure and therefore higher oil yield. An optimum should be found for each individual press.
- **Moisture content of the seeds**: this is related to storage. An optimal moisture content of 2-6% was identified. Moisture content of > 8% should be considered too humid and needs more drying.
- **Hull content of the seeds**: This is a difficult variable. Ideally one would like to press jatropha without its hull. However, the hull appears vital to pressure build-up inside the press. Removal of the hull would require less energy for pressing and result in zero presence of hull fibers in the crude oil. Unfortunately seeds without a hull turn into a paste inside standard expellers, which sticks to the worm and keeps rotating along with it. Adaptation of the press is required to increase the friction with the press chamber.

4.2.3.2 Oil quality

The oil quality is affected by:

- **Moisture content of seeds:** according to fuel norms the water content in SVO should be below 0,08% (figure 23). High moisture content might also increase the formation of FFA during storage.
- **Process temperature:** the friction inside the expeller generates heat, which is passed on to the oil and press cake. Above certain temperatures phosphor is formed, which leads to carbon deposits on fuel injectors and combustion chambers. For rapeseed oil, for example, the maximum temperature of the oil during the process is 55-60°C. For jatropha the exact temperature at which phosphor starts to dissolve in the oil has not yet been determined. A value comparable to rapeseed is expected.
- **Hull content of the seeds:** lower hull fraction in the seeds leads to lower pressures and thus less hull fraction in the crude oil. Partial dehulling is a direction for further investigation.
- **Pressure:** higher pressure leads to higher temperature and more solid particles in the crude oil.

4.3 Press technologies and expeller types

A distinction can be made between hand-operated oil presses (e.g. ram press) and mechanically driven ones (e.g. expeller). For small pressing capacities, in the range of 1-10 kg seed/hr, ram presses and expellers are both suitable options. For pressing more than 10 kg/hr, hand-operated presses are no longer possible and expellers should be used.

Different categorizations can be made between the several types of presses:

1 Continuous operation vs. batch operation

2 Manually driven vs. engine-driven, where for the latter a distinction can be made between electrical engines and diesel engines
3 Cold-pressed vs. hot-pressed.

In the oil-processing industry, a distinction is made between different process types. The first distinction is between batch and continuous. Most hand-operated presses operate in batches. Ram presses use the combination of piston and cylinder to crush the seeds and squeeze out the oil. Operation of the press is easy and can be done manually. Expellers can be operated in a continuous way. As noted earlier, for oil production of more than 5 liters/hour, continuous expelling is a necessity.

For rural applications in developing countries, both manual and small engine-powered presses are viable, depending on the location and the application. Soap or medicinal oil can be made in small quantities with a hand press. In case of fuel production processes, engine-powered presses are more sensible.

The third distinction is between cold pressing and hot pressing. Cold-pressed means the temperature of the oil does not exceed 55-60° C during the process. For hot pressing external heat is often applied to seeds or press and the temperature can increase to over 100 °C. Hand operated presses fall in the category of cold pressing. Due to the higher pressures and friction in an engine driven expeller, cold-pressing temperatures will be exceeded. Cold pressing is most desirable for jatropha, although it is not always possible due to high friction in the expeller.

4.3.1 Ram presses

The most well-known representative of this category is the Bielenberg ram press. Based on an existing design of a ram press that was expensive, inconvenient and inefficient, Bielenberg made the design of his press that would be cheap, durable, locally maintainable and easy to use. Several hundreds of these presses have been manufactured by local workshops in Tanzania, leading to good quality at an attractive price, which has lead go good adoption. The Bielenberg press was originally designed to press sunflower seeds. It is applicable for jatropha seeds as well, although with reduced efficiency. The capacity is limited to 2-3 kg/hr. At a recovery rate of 70-80% and an oil density of 0,918 kg/liter this means < 1liter/hr.

Figure 2 – the Bielenberg ram press operated at Kakute Ltd., Tanzania [12]

Figure 3 – close-up of the Bielenberg pressing mechanism. Notice the automatic discharge of

the pressing chamber and the stopper in the seed funnel [12]

4.3.2 Expellers

Expellers are also referred to as screw presses. However, in this report only the word expeller will be used as it describes what the process does - is expels oil from solids. Nearly all the mechanized presses that can be found on the market use a continuous pressing process. Usually this involves an endless screw that rotates in a cage and continuously kneads and transports the seed material from the entry funnel to a nozzle where pressure is built up. Over the length of the screw the oil is expelled from the seeds and flows from the side of the screw to a reservoir. At the nozzle the seed material is maximum compressed to a press cake. All expellers can be categorized as either 'cylinder-hole' type or 'strainer' type (see figure 4 and 5).

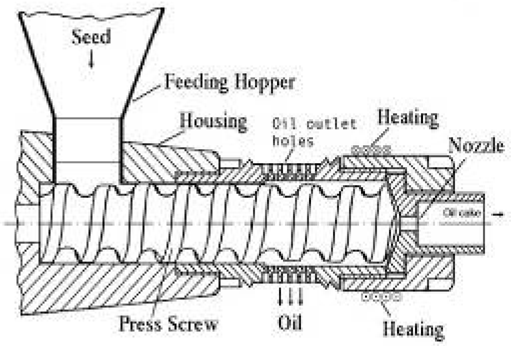

Figure 4 – schematic drawing of cylinder-hole type press. Notice the nozzle that can be changed [4].

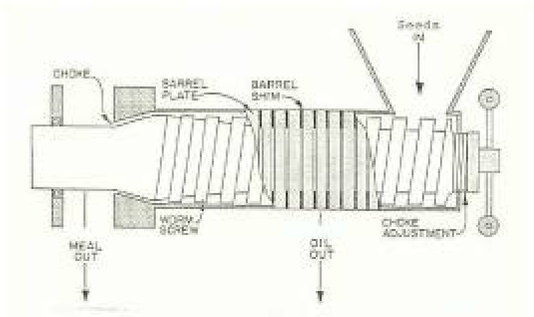

Figure 5 – schematic drawing of the strainer type press. Notice the choke adjustment that is on the opposite side of the choke itself [4].

4.3.2.1. Cylinder-hole

In the 'cylinder-hole' type, the oil outlet is in the form of holes at the end of the cylindrical press cage (figure 4). The seed gets a rising compression in the direction of the press head. The oil is pressed out of the seeds near the outlet holes and drained from them. Special cavities near the nozzle prevent the cake/seed-mix from sticking to the screw. Otherwise, there would be no forward movement. The presscake is pressed through changeable nozzles and formed to pellets. In most types of presses the nozzle is heated to avoid blocking of the presscake. Cylinder-hole type presses exist for small capacities (up to approximately 200 kg/h seed). For different types of oilseeds the press can be adjusted by changing the nozzle diameters and screw rotation speed.

4.3.2.2. Strainer

The strainer type press has an oil outlet over the full length of the press cage that serves as a strainer. The strainer is actually a cylindrical cage built-up of separate horizontal bars or vertical rings arranged at a small interspacing. The spacing between the strainer bars can be either fixed or adjustable. Strainer presses come with various screw design although the principle of all screws is similar. The screw diameter increases towards the nozzle thereby increasing the compression of the solid material. Screws for continuous compression are made from one piece. For some seeds, the oil recovery is higher after multiple compression steps. A screw with multiple compression section can be used to create multiple compression stages to increase oil outlet. For flexibility, subsections of different size and shape are often available. Other presses are equipped with different screws.

During the flow of the seed through the press, the oil is drained via the strainer, which surrounds the pressing space. The choke size can be adjusted to change the pressure level and distribution. For several types of oilseeds, it is necessary to change the gap size of the strainer bars (interspacing) where the oil comes out, to get an optimal yield and cleanness of the vegetable oil. In addition the choke size and the rotation speed should be adjusted when pressing different kinds of seed. Strainer presses exist in a wide capacity range from approximately 15 kg of seed/hr to 10 tonnes of seed/hr.

Figure 6 – The Danish BT press is an example of a cylinder-hole type press. Notice the nozzle, left in front [10].

Figure 7 – The Sundhara oil expeller is a representative of the strainer type presses. On the right side the choke adjustment. [12]

Does it matter which of these two press types you use? Experience from FACT indicates that for jatropha it does matter. It was concluded that strainer presses are preferred over cylinder-hole presses. In figure 8 the two expeller types are qualitatively compared in suitability to press jatropha seeds.

	Cylinder hole press	Strainer press
Throughput	-	++
Ease of maintenance	+/-	+/--
Price	+/-	+
Oil yield	++	+
Robustness	+/-	+
Ease of operation	-	+
Wear resistance	-	+

Figure 8 - Comparison between strainer and cylinder-hole press based on FACT experience.

4.3.3. Power required

To press oilseeds, as in all production processes, power is needed. Small presses like the Bielenberg ram press can be powered by hand, by one or several operators. Capacity is then typically 3-5 kg seed/h. One hour of press operation costs 3000 kjoules if operated by 2 persons[1] and roughly produces 1 liter of oil. This comes down to an energy consumption of 0.85 kWh/liter.

Larger capacity presses, especially the expellers, are engine driven. In general, electrical engines are chosen because of their ease of installation, coupling & operation and low cost. As a rule of thumb 1-

[1] Based on the energy used for sawing wood http://mens-en-gezondheid.infonu.nl/dieet/6131-energiebehoefte-en-energieverbruik.html

2.5% of the energy content of the produced oil is used as input power [2]. It is, however, perfectly possible to couple the press directly to a diesel engine to be independent of grid – the diesel engine can even run on the jatropha oil that it is pressing. In case an expeller is powered by a diesel engine, the energy input will be 5-10% of the energy content of the produced oil [8]. Because of the superior oil recovery rate of the expeller this comes down to 100-200 kjoules/kg or 0.30 kWh/liter. From an energy efficiency point of view the expeller is preferable, although one should keep in mind that the electricity or fuel required are not available in many rural areas.

4.3.4. Suggested models

It is impossible to suggest an optimal expeller model for jatropha for all cases. The selection depends on many factors, including the production capacity, final purpose for the oil, rural/urban location, distance to supplier, reliability and ease of supply chain, the level of technology in the country and last but certainly not least the budget. A complete overview of manufacturers and models is given in appendix 1. For the rural projects intended by FACT, only capacities ranging from 10 kg/hr (hand press) to 500 kg/hr (engine driven expeller) should be considered viable options [8].

What to keep in mind:

- What equipment is available in the country where the jatropha project is located?
- Is the production capacity below or over 100 kg/hr? (This is typically the smallest expeller capacity)
- If production is over 100 kg/hr do you want one press or several?
- Is efficiency more important than investment costs?
- What are the ease, speed and reliability of the supply chain?
- Consider the drive train of the press, either with diesel engines (on SVO/diesel) or electrical driven.
- Will the ‘power take-off’ be with pulleys and belts or with gears?
- What is the required maintenance? What about and spare parts?
- Consider the training of operators.
- What is the operational temperature of the expeller? (Too high temperature causes amount of phosphor in the oil to increase)

In general, one should choose a single press of large capacity instead multiple smaller presses. However, the advantage of using more than one press is that parts can be exchanged and production can still continue at a lower level if one of the machines fails. Furthermore, smaller machines are easier to operate and maintain for local artisans. Smaller machines also allow production capacity to modularly increase over time with project size by just increasing the number of expellers.

4.3.5 Concluding remarks expellers

Expelling can be defined as the process step that determines production efficiency. The higher the oil recovery and the lower the amount of solid particles in the crude oil, the higher the efficiency. Lower amounts of solid particles reduce the need for subsequent cleaning. Industrial press suppliers have already conducted jatropha tests with sediment levels as low as 5%. All fuel-related production should use mechanically driven expellers. Activities like soap making or cosmetic oil production could use manually operated presses like the Bielenberg. The choice of technology depends on the specific project. If presses are locally manufactured to an acceptable quality standard compared to costs of replacing spare parts, this can be a good solution as the technology is known and parts are available. In other cases European presses are superior regarding robustness and wear resistance, but more expensive than their Indian and Chinese counterparts. Selection is always a tradeoff.

4.4 Cleaning of vegetable oil

This section provides an overview of the available cleaning technologies for solid/liquid separation of crude jatropha oil. The oil that leaves the expeller directly after pressing is further referred to as crude jatropha oil. The crude oil contains significant amounts of solid material that need to be removed. The solids can be mechanically separated from the oil, based on particle size (filtration) or on specific gravity (sedimentation, centrifuging). The two separation principles can also be used in series. Sections 4.4.1 through 4.4.3 will successively treat sedimentation, filtration and centrifuging.

The crude jatropha oil leaving the expeller contains 5-15% solids by weight. This comes down to 10-30% by volume, depending on what the sediments are. In addition, the circumstances during pressing and the intended application for the oil may require further processing of the crude oil. For soap-making and lamp fuel, the quality requirements are less stringent than when applying the jatropha oil in a diesel engine. In most cases, vegetable oil produced by cold pressing does not require degumming and neutralization. However, presses appear to operate at much higher temperatures when processing jatropha compared to rapeseed. A typical processing temperature for rapeseed is 45-50°C. Measurements in a Danish BT50 (80-100°C, thermocouples in press head) and a Keller P0100 (75°C, infrared measurement) show values above 70°C. If rapeseed reaches temperatures above 60-70°C the oil requires an additional neutralizing step to remove the phosphor that dissolved into the oil under the influence of heat. Whether or not this can be extrapolated to jatropha oil is unclear at the moment, but it is at least something to keep in mind. Pressing at higher temperatures yields more oil but in exchange requires these additional cleaning steps.

As cleaning is most important for fuel production, the section below applies mainly to fuel production. Prior to use in a diesel engine the oil should be free of all particles > 5 µm to prevent clogging of fuel filters. Normal diesel fuel filters have a pore size of 5-10 µm. The cleaning process should follow shortly after the pressing process to avoid filtration problems when the oil was stored under unfavorable storage conditions (see section 4.6).

To assure good SVO quality the German DIN V 51605 was introduced in Europe in 2007. This norm is based on the earlier 'Quality standard for rapeseed oil as fuel 5 / 2000' from the German Bavarian State Institute of Agricultural Engineering, Wiehenstephan. In order to minimize the negative effects on engines, SVO from jatropha should comply with this DIN V 51605 norm for plant oil. The standard is described in section 4.5 and shown in figure 13.

4.4.1. Impurities in the oil

The crude jatropha oil contains many impurities. This section gives a first idea of the types of impurities and underlines the necessity of cleaning steps. The impurities present in jatropha oil consist of both dissolved and suspended particles that are not part of the structure of the oil. Solid particles, FFAs and phosphor need to be removed before the oil is ready to use in engines. Removal of these impurities is also required to prevent deterioration of the oil during storage. Water (both free or intermolecular) will, for example, hydrolyze the oil and stimulate the formations of FFAs. Pro-oxidant metals like copper and iron will speed up oxidation. Dust or solid particles that might have not been filtered from oil will not affect the oil itself but the usage of the oil will be more difficult. It is therefore important to monitor feedstock (moisture level & freshness) and oil quality after cleaning.

4.4.2. Sedimentation

Sedimentation is the simplest and cheapest way of cleaning by using the earth's gravity: the solids settle at the bottom of the tank. Sedimentation is only recommended for small processes. For production rates of < 50 liters/hr sedimentation is a preferred low-cost solution. It requires little technology and efficiency losses are less important when producing small volumes. It is a cheap cleaning method because little hardware needs to be purchased… only a storage tank large enough to keep the oil for about a week with little or no flow. If necessary, the process can be completed in multiple stages as shown in Figure 9.

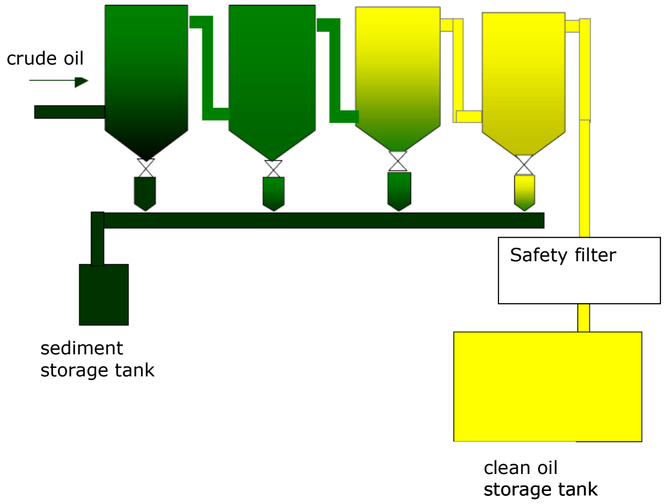

Figure 9 – example flow diagram of a sedimentation system [4].

Figure 10 – oil drums for sedimentation [picture Diligent Tanzania Ltd.]

One disadvantage of a sedimentation system is that it depends on optimal conditions to remove particles with sizes of 8 µm and less [2]. Therefore a security filter (bag filter or candle filter) is required. Sedimentation alone is not enough to produce good fuel quality. Additionally the relatively high amount of oil that remains in the sediment (50-55%) is lost if no further steps are included. Both available alternatives, filtration and centrifugation, have higher oil yield, assuming the input product meets the filter's requirements.

4.4.3. Filtration

The basic principle of filtration is blocking any particles bigger than the pore size in a membrane. The easiest way of filtering is by using a cloth. However, be aware that not every textile has a suitable pore size! The capacity to absorb particles, referred to as the nominal capacity, differs between materials. A nominal capacity of 85% for a cloth with pores of, for example, 5µm means that 85% of the particles bigger than 5µm are stopped by the cloth. Special filtering cloth or bag filters can be bought at various suppliers, like Monopoel, amafiltergroup or local suppliers. The cloth is available in sheets (see figure 11) or as bags, for example. Filtering is easier at lower viscosity of the oil. A temperature between 40-55°C would be optimal. Make sure the filter cloth is resistant to these temperatures. If not the mesh may widen and a 5µm filter may only filter up to 20µm [5].

Filtering methods

Five methods for filtering will be described here. The most simplified custom-made solution is gravity filters (bags and band filter) using cloth or filter bags. These require little machinery or electricity (figure 11-13). These simple solutions are best suited for small rural activities. In addition to custom-made systems, suppliers offer professional systems. These are often too expensive for processes <50 liter/hr. The following will be explained here: gravity filters, band filters, filter press, pressure leaf filters, bag filters and candle filters.

4.4.3.1. Gravity filters

As explained above the quality and pore size of the filter cloth are important determinants for the final result of filtration. Using a 1µm filter cloth in simple custom-made devices yields oil with quality comparable to industrial filter systems with the same pore size. Cotton bags are available with different pore sizes, ranging from 200 µm to 1µm. It is advisable to finish with a 1µm pore size for fuel production. The disadvantage of simple devices is a very low capacity if the filter is not pressurized. For home users and small factories (up to a few liters per hour), non-pressurized filters can be an attractive low-cost option as the process can run without purchasing special hardware.

Handling will in that case consist of frequent cleaning of the filter cloth or bag filter. It is recommended to leave the oil to settle for 4-7 days before filtering to avoid even shorter changing intervals of the filter cloth. Depending on how clean the oil is after sedimentation, filtering oil through gravity takes between 5 minutes to 1 hour per 20 liters [11]. The sediment in the oil should be considered a process loss or can be used as input material for the production of biogas in a digester.

Filter bags can be obtained through for example amafiltergroup or 'Allfil filtertechniek' in the Netherlands. Suppliers can be found worldwide. One bag is sold for around €3.75 (amafiltergroup, 2008). Locally available cotton material might also prove suitable after testing.

Figure 11 – Left top: SVO filtration of cooking oil on the site of German supplier Monopoel. Right top: simple filtration setup using bag filters [picture Diligent Tanzania ltd.]. Left bottom: improved setup for bag filters [picture Diligent Tanzania ltd.]. Right bottom: employee collecting an oil sample for analysis after filtration [picture Diligent Tanzania ltd.]

4.4.3.2. Band filter

The use of bag filters under gravity has very low processing capacity and requires frequent cleaning of the bags. Therefore FACT engineered a solution at a project in Honduras. The band filter prototype in figure 12 was engineered by Ger Groeneveld. It consists of K&C workman's cloth X70 on a roll construction to create a moving filter cloth. The key factors to performance of the device are: the entire filter area is used, there is constant removal of sediment without interrupting the filtration process, and there is constant quality due to use of gravitational force for separation. The moving cloth on the band filter helps to reduce clogging problems and enables easier cleaning. The capacity of this model is 20-60 liters/hour for a filter cloth with 5 µm pore size [5].

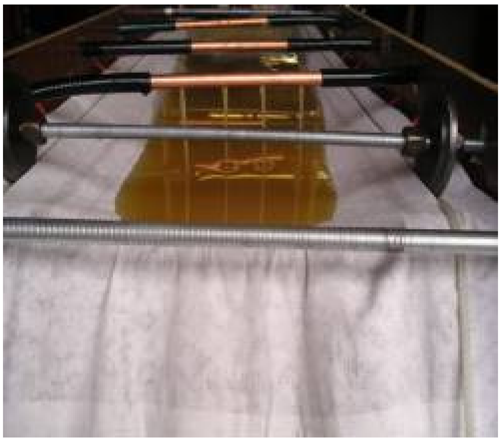

Figure 12 – Top view of the band filter where the crude oil flows onto the filter cloth.
[5].

Figure 13 Band filter in operation. The transport rollers are equipped with sandpaper for better friction. The cloth is continuously moving.
[5].

4.4.3.3. Filter press

If using pressurized bag filters, a different type of filtration is needed in advance. Otherwise the filter will clog after several minutes. For that reason the filter press and pressure leaf filter are discussed here first.

Filter presses are widely applied in the food industry and are often locally available in different sizes. Use of local machinery stimulates employment and enables local engineers to provide both repair and maintenance. Local training programs could be a stimulus and might increase quality standards.

A filter press is build up of multiple filter plates that are sheathed with filter cloth (figure 14 & 15). The filter cloth material can be used several times before cleaning. When the plates are pushed together cavities are formed between them. Before filtration the crude oil flows into the cavities. By applying hydraulic pressure on the plates and pumping pressure on the oil, the oil is forced through the cloth and the filter cake remains in the cavities. Oil keeps running through the filter until there is too much cake in the cavities. The plates are then separated (either manually or automatically) and the presscake falls off. Manual cake discharge takes about half an hour per day for rapeseed and depends on the level of 'impurities' in the oil [11].

How does this compare to jatropha oil? The following key numbers apply to rapeseed oil: oil content in the filter cake of about 35-50% and 2-4 kg of filter cake after processing 100 kg of rapeseed. For jatropha, the amount of filter cake after processing 100 liters of crude oil is expected to be 15-25 kg with an oil content similar to rapeseed. This means that cake discharge will be 5-10 times as frequent, which comes down to 2.5-5 hours per day. This is clearly not practical. Therefore sedimentation is still required before most filtration methods due to the high amount of sediments in jatropha oil.

After discharge, the process cycle restarts. The membrane pore diameter is intentionally chosen larger than the size of the particles that have to be removed. A filter press has to be used for some time in a closed-loop situation to build up a layer of particles (cake) against the membrane. This way the sediments in the oil form the actual filter medium. Whether or not the sediment layer is a proper filtration medium depends on the particle size distribution. In case all particles are of the same size the layer will easily clog.

The capacity of a filter press is directly proportional to the filter cloth area in m^2 and can therefore be easily adapted. Smaller mesh sizes result in lower throughput and it is therefore uncertain what the processing speed will be at the desired purity of the output product. Although the filter press is capable of removing particles <0.01µm it is advised to install a bag filter candle filter behind the filter press for safety cleaning. Depending on the size of the plate filter the oil content in the filter cake will normally be around 10% [11].

Figure 14 Plate filter with capacity of 150 liters/hour. At Diligent Tanzania ltd. Produced by TEMDO Tanzania.

Figure 15 Plate filter for food industry, capacity around 1000 liters/hour.

4.4.3.4. Pressure leaf filter

The pressure leaf filter consists of a cylindrical filter vessel filled with filter plates. Similar to the filter press, this filter first builds up a layer of particles in closed-loop operation.

Crude oil enters the vessel and can only leave through the hollow frame surrounding the filter plates. To enter the hollow frame the oil first needs to pass through the filter plate where the solid particles are then stopped. When the filter vessel is full the system is pressurized by pumps to 10-15 bar, after which the oil starts flowing and the solid material in the oil forms a layer on the filter plate. This plate serves as the actual filter medium.

A pressure leaf filter is capable of filtering particles > 10-20µm, depending on the selected mesh size. If the amount of sediments in the crude oil is >10% a sedimentation step is required upstream of the pressure leaf filter. As a guideline for the pressing process, before filtration an oil content in the press cake of >12% is considered optimal. Reduction of the oil content in the press cake to for example 8% by second pressing results in fines in the oil and lower filter capacity (amafiltergroup). After the pressure leaf filter almost all particles >10-20µ will be removed from the oil. Additional filtering steps will be required before the oil can be used as fuel.

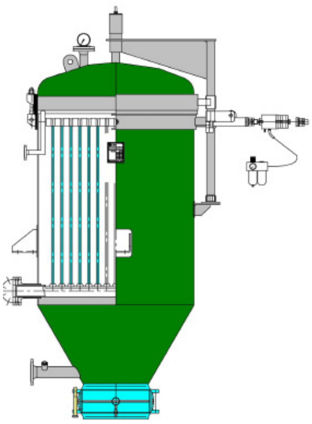

Figure 16 drawing of a pressure leaf filter [picture amafiltergroup].

Figure 17 Close-up of one of the filter plates. The framework around the mesh is made of hollow tubes that serve as a discharge for the clean oil [picture amafiltergroup].

4.4.3.5. Bag filters

Bag filters use the same principle as custom-made filters but are pressurized by an electrical fluid pump to enable higher throughput. The bag filter consists of a filter housing with a removable basket fitted with a filter bag, similar to the ones used for gravity filtration. Figure 18 shows an impression of the bag filter. Typical operating pressures are 3-5 bar.

A bag filter of 1µm, means that particles >1µm are removed at a nominal efficiency of 65-98%. This means that the quality of the output product fluctuates. To cover for these fluctuations a candle filter is normally added to the process. Bag filters generally have to be cleaned every 14 days. Some examples of Dutch suppliers are amafiltergroup, EFC filtration and Allfil filtertechniek. The price of a bag filter ranges from €500-€1000 without electrical pumps and €1000-€1500 with pumps included. Other modules like the electrical pump, hoses and storage tanks can be bought locally, if desired. A bag filter is suitable for >50 liter/hr process flows. Attention: sedimentation or pre-filtration are necessary prior to running the oil through the bag filter. When trying to filter crude oil directly after pressing, the bag filter will clog within minutes.

Figure 18 Stainless steel filter housing unit for a bag filter (without pump or storage), at Diligent Tanzania ltd.

Figure 19 Filter housing with filter basket from www.amafilter.nl. The filter bag is inserted in the basket and need cleaning every 14 days.

4.4.3.6. Candle filters

Candle filters are often referred to as polishing filters as they perform the final touch in the cleaning process. This means the oil already needs to be quite clean before entering the filter. A candle filter of 1µm means that particles >1µm are removed at a nominal efficiency of 92%. The candle filter is stable, which guarantees product quality. A single candle can support approximately 60 g of solid material before it needs changing. When fed with pre-filtered rapeseed oil candles need to be replaced every 6-8 weeks. If a bag filter is installed in front of the candle filter similar maintenance intervals are to be expected for jatropha oil.

The costs for a candle-filter housing are comparable to the bag filter. Candles cost approx. €75 per set for a throughput of 200 litre/hr, which is €500-€650 per year when changed according to the maintenance interval of 6-8 weeks. Note that the candles cannot be cleaned like the filter bags. An increase in operating pressure indicates that the candles need replacing.

Figure 20 Combined setup of a bag and candle filter form amafiltergroup. [picture Diligent Tanzania ltd.].

Figure 21 Candle filter housing with filter candles from www.amafilter.nl. The candles need to be replaced by new ones every 6-8 weeks.

4.4.4. Centrifuging

In addition to sedimentation this is the second method of separation that is based on specific gravity. The reason for mentioning it only at the end of this chapter is that it is not suited for small projects. However, it is worth mentioning the working principles of this technology might provide ideas on how to develop low-cost alternatives.

4.4.4.1. Decanter & separator

Using centrifugal force for particle separation is a fast alternative to sedimentation. Both decanters and separators are industrial devices that work according to this principle. Decanters and separators use the difference in specific gravity between media.

For solid-liquid separation the liquid viscosity and density difference between solids and liquids determine if the residence time in the centrifuge is enough to enable separation [11]. Solid content and particle size are of subordinate importance as decanter settings can be adjusted. Decanters and separators are successfully used in almost all industrial separation processes involving food and beverage. Due to their high prices and capacities they have not yet been applied in jatropha-related projects. Although they are perhaps the best separation technology for jatropha oil, decanters/centrifuges are generally not an option for capacities below 500-1000 liter/hr. For such capacity the price will be around €50.000.

Figure 22 - Picture of the Z23 decanter with capacity of 500-1000 litre/hr [picture Flottweg

Figure 23 - Picture of a disc centrifuge AC100 [picture Flottweg Nederland BV].

Figure 24 - Example of a centrifugation system with a bag filter as a security [12].

Nederland BV]

4.4.5. Concluding remarks oil cleaning

Oil cleaning is the process step that determines product quality. Although many technological solutions are available one should always apply the KISS (Keep It Simple Stupid) principle when selecting one in a development project.

Sedimentation is still the most favorable solution for small production volumes (< 50 liters/hr). Filtration and centrifuging technologies are generally too expensive for most projects involving farmer groups. Development of simplified versions of such technologies could provide a welcome solution in these projects. Simple filtration constructions are the best candidates for a final cleaning step for the oil that is skimmed off after sedimentation. Proper pore size of 1µm ensures a SVO free of particle contamination.

4.5. Quality standards for SVO

Different applications of jatropha oil require different levels of quality. In most cases jatropha oil will be used for one of these three applications:

- **Soap-making***:* proper filtering of the oil is sufficient for this process.
- **Lamps and stoves***:* proper filtering of the oil is sufficient for this process. Reduction in viscosity would be desirable to improve fuel flow in wicks and nozzles.
- **Diesel engines***:* oil should comply with DIN 51605 norm to minimize the chance of engine damage. In general the amounts of FFA and phosphor will be most problematic and require chemical cleaning. Phosphor and FFA can subsequently be removed by degumming and neutralizing.

It can be concluded that quality is mainly an issue when the oil is used in engines. For the use of rapeseed oil as a fuel in Europe a quality standard has been developed that contains the characteristics of the oil that are important and their limit values. As can be seen in the diagram below, DIN standards document the exact procedure of determination of the properties. A distinction is made between two kinds of properties, the characteristic ones that depend on the oilseed used, and the variable ones that depend on the processing used (pressing, filtering, after treatment, etc.) Although this standard has been developed for rapeseed oil, the limiting values also apply to other oils like jatropha because they are mostly related to the use of the oil in engines.

Properties/constituents	**units**	**Standards**
Density at 15 °C:	900-930 kg / m³	according to DIN EN ISO 3675 or DIN EN ISO 12185
Flash point: min.	220 °C	according to DIN EN ISO 2719
Kinematic viscosity at 40 °C max.	36,0 mm²/s	according to DIN EN ISO 3104
Calorific value: min.	36000	according to DIN 51900-1, -2, -3
Ignite: min.	39	
Carbon: max.	0.40%	according to DIN EN ISO 10370
Iodine value	95-125 g g Iodine/100	according to DIN EN 14111
Sulpfur content	10 mg / kg	according to DIN EN ISO 20846 or DIN EN ISO 20884
Variable properties		
Total pollution	24 mg / kg	according to DIN EN 12662
Acid number	2.0 mg KOH / g	according to DIN EN 14104
Oxidation stability at 110 °C: min.	6.0 h	according to DIN EN 14112
Phosphorus content: max.	12 mg / kg	according to DIN EN 14107
Total amount of magnesium and calcium: max.	20 mg / kg	according to DIN EN 14538
Ash content (Oxidasche): max.	0.01%	according to DIN EN ISO 6245
Water: max.	0.08%	according to DIN EN ISO 12937

Figure 25 – DIN V 51605 norm for rapeseed, based on the earlier Weihenstephan or RK2000. The DIN V 51605 standard summarizes the criteria that determine the quality of SVO as an engine fuel [7]. FACT recommends using this norm for jatropha oil in diesel engines as well.

To make sure the properties of the oil are within the desirable range, several things have to be kept in mind. The variable properties are briefly discussed, together with their consequences for the production process.

- **Contamination**: this describes how much foreign material (particles) may be present in the oil. Of course this parameter is directly influenced by the purification process. The contamination value determines the lifetime of the engine's fuel filter.
- **Acid value**: this is a measurement of the content of free fatty acids in the oil. Free fatty acids give rise to degradation of the oil (it gets 'rancid') and the components in contact with it (oxidation). Their formation is mostly caused by bad storage conditions, i.e. contact with air, exposure to sunlight, heat etc.
- **Oxidation stability**: the oil quality should not degrade in a hot environment. This is because the fuel is exposed to high temperatures when it is in use. The mechanisms are the same as explained under 'Acid value'.
- **Phosphorus content**: in cold pressing most of the phosphorus that is present in the seed goes into the presscake and not into the oil. That is desired because phosphorus (especially phospholipids) gives rise to blocking of the engine's fuel filter and to oxidation of the combustion chamber because phosphorus is a strong oxidator at high temperatures.
- **Ash content**: the ash content reflects the amount of material that remains unburned after combustion of the oil in the engine. Most of this material is salt present in the oil. It can be kept low by gentle pressing and good filtering.
- **Water content**: the plant material contains a percentage of water. In the oil the water content should be limited, because water causes the fuel filter material to swell and hence block and water causes oxidation inside the injection equipment.

Some components cannot be removed from the oil by the cleaning methods treated in section 4.4. Examples are free fatty acids, phosphor, and different molecular contaminations (Fe, Mg, Ca etc). By restricting the operation temperature during pressing to ~60°C (specific temp for jatropha has not yet been determined) the formation of FFA and phosphor can be limited. At excessively high levels, further refining might be required to assure smooth operation in diesel engines. Standard refining steps in industrial production of both consumer and fuel oils are degumming and neutralizing.

4.5.1. Oil degumming

The DIN 51605 norm states that phosphor content should be below 12mg/kg. Phosphatides, gums and other complex colloidal compounds can promote hydrolysis (increase in FFA) of vegetable oil during storage. In further refining steps such as transesterification these compounds can also interfere. They are therefore removed by a process called degumming. The process starts by heating the oil to 70-80 °C. Then water is added and stirred. The gums and phosphatides will dissolve in water and removed together with the water in a separation step. Depending on the type of oil and phosphatide content acid (citric/phosphoric), base or salts can be added instead of water [16].

4.5.2. Oil neutralization

According to DIN 51605, the acid number should be below 2 mg KOH/g. This corresponds with an FFA content of 1%. When the free fatty acids are removed as soaps by treatment with lye, other undesirable constituents such as oxidation products of fatty acids, residual phosphatides and gums, phenols (e.g., gossypol) are also “washed out”. During neutralization the oil is again heated to 40-80 °C. NaOH or KOH are added and stirred, causing the formation of soap. The soap, containing most FFAs, settles at the bottom of the tank and can be removed [16].

4.6. Handling and storage of oil

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There are several issues to take into account, which affect the oil quality and ease of handling. These are especially important if the oil is stored at high temperatures in rural areas.

4.6.1. Handling criteria

There are toxic ingredients in jatropha oil (phorbol esters), which make it necessary to handle the oil with care.

Eye contact causes irritation, whereas ingestion can result into vomiting and diarrhea. Skin contact is essentially non-hazardous, but wearing safety gear (overalls, goggles and closed shoes) is advisable.
Prevent the oil from entering drains, surface and ground water. Although vegetable oils are biodegradable, when entering water they cover the surface. This results in a layer that prevents air exchange with the water, as well as with the creatures living in the water. When in contact with water the hydrolysis results in the formation of carbon dioxide, which results to carbon imbalance in water.
Also avoid the inhalation of fumes. Please look at the enclosed Material Safety Data Sheet (MSDS) (Appendix XXX) on how to minimize the hazards. A MSDS is a form containing data regarding the properties of a particular substance. It includes instructions for the safe use and potential hazards associated with a particular material or product

4.6.2. Storage criteria

Store in a cool, dry room, avoiding exposure to light and potential volatile gaseous substances (like petrol). The container or drum in which the oil is kept should preferably be airtight and filled up to the maximum. This prevents condensation and thereby water in the oil. Storage containers or drums can be reused and should therefore be easy to clean. Steel or hard plastic, the normal materials for these drums, can be used to store or transport the jatropha SVO.

4.6.2.1. Cool storage temperature

Vegetable oils contain enzymes that originated from metabolic activities during the plants growth. The activity coefficient of enzymes doubles with each 10 degree centigrade increase. This shortens the life of oil during storage as it promotes auto oxidation of the oil. This will result in fast colour change and an increase in free fatty acids in the oil.
It is therefore important to keep the storage area cool, in order to prevent instability and an increase in FFA. Most of the enzymes in the oil become more active at a temperature above 30 degrees centigrade. Therefore it is advised to store oil at a temperature lower than that.

4.6.2.2. Avoiding temperature variations (and hence water condensation)

If the jatropha oil is kept in a drum, IBC (International Bulk Container, 1000 liters) or other storage containers, temperature variations can cause condensation of water. This means water will be dissolved in the oil, which is not good for the quality of the oil.

The temperature should therefore be kept, as much as possible, at the same level. Another way of avoiding condensation is to keep the container airtight and filled to the maximum.

4.6.2.3. Darkness

Vegetable oils are from plants and contain photosensitive compounds like chlorophylls and carotenoids. Among these compounds, chlorophyll is what causes the oil to appear yellow or red. In the abundance of light these compounds activities fastens and results in strong color change in the oil. To avoid this it is recommended to store oil in dark areas or in areas where the light intensity is low. In general this means selecting a non-transparent storage unit.

4.6.2.4. Contact with fresh air

Under unstable oil storage conditions like elevated temperatures, it is easy for the oxygen present in air to oxidize the multiple bonded carbon atoms and replace the fatty acid in that area. This will then form per-oxide compounds. The increase in these compounds results into more unstable oil.
It is difficult to prevent contact of air with oil using the normal container seal cap. In recent times nitrogen has been used to fill containers holding oil to prevent contact with atmospheric oxygen, as it is not as reactive to oil. Vacuum systems can also be used, but they are quite expensive.

4.7. Literature

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